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(71) Applicant
Rockwell International Corporation

(Incorporated in the USA - Delaware)

1200 N Alma Road, Richardson, Texas 75081, United States of America

(72) Inventor
Wesley J Runyan

(74) Agent and/or Address for Service
Reddie & Grose
16 Theobalds Road, London, WC1X 8PL, United Kingdom

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(54) **Fluorescent lamp dimmer**

(57) The brightness of a fluorescent lamp 302 can be controlled by adjusting the level of direct current provided by a current regulator 500 and by adjusting the ON pulse width of transistors 410, 420 in an inverter 400 which energises the lamp 302 and is supplied by the regulator 500. The regulator 500 comprises an inductor 514 and a switching transistor 506 controlled by a pulse width modulator 516 responsive to the comparison by transistors 541, 542 between the current sensed by a resistor 533 and a reference level 538. A further inverter 600 which supplies the lamp filaments 304, 306 has a pulse width controller 624.

In order to conserve power and extend lamp life time the filament power may be varied by adjusting a control input 657 to controller 624 as the brightness command input signals 538 to regulator 500, and 490 to a pulse width controller 460 in inverter 400, are adjusted. The controllers 460 and 624 are operated in synchronism with modulator 516 at a clock rate determined by a capacitor 519 and a resistor 521. The command signals 538, 490, 657 may be adjusted by potentiometers 530, 464, 644 or generated from a master dimming signal.

The arrangement may provide a dimmable backlight for an avionics display.

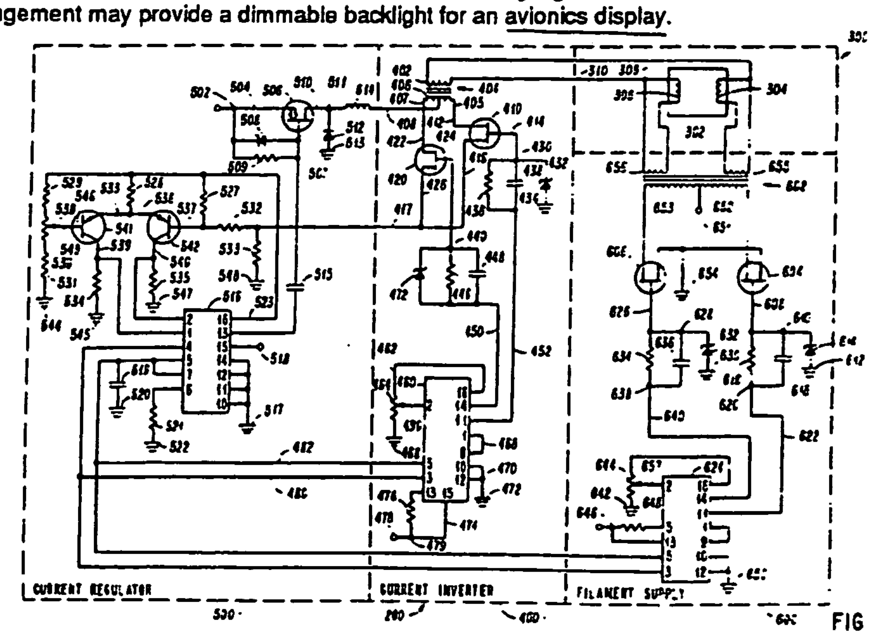


FIG 2

2212995

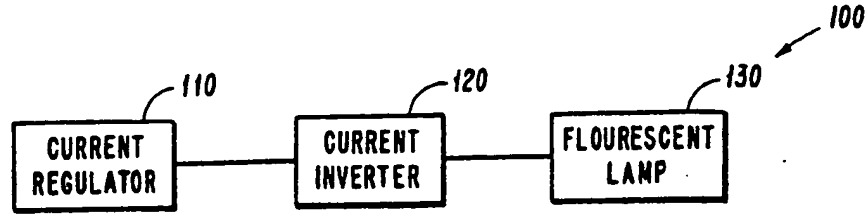
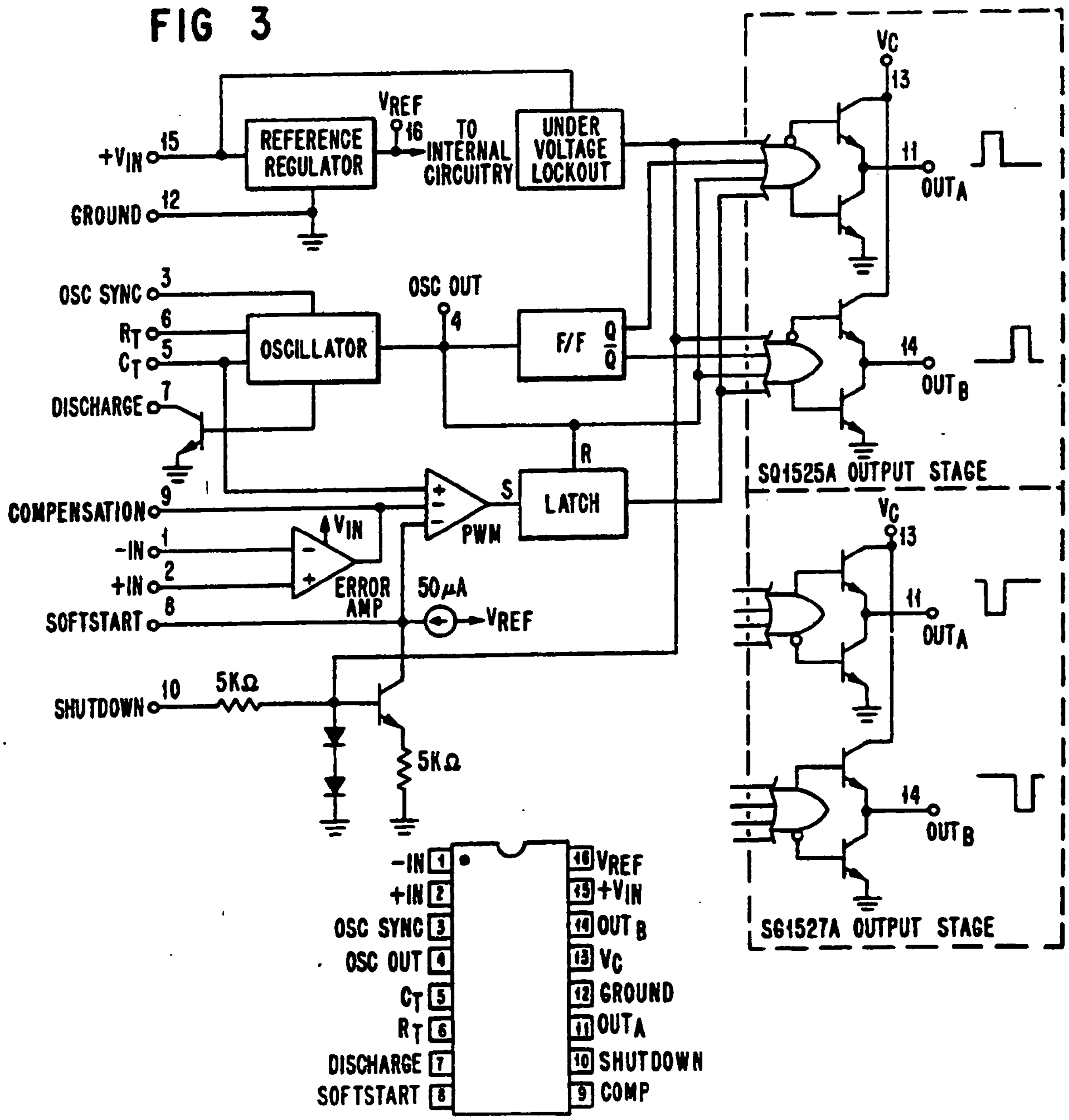
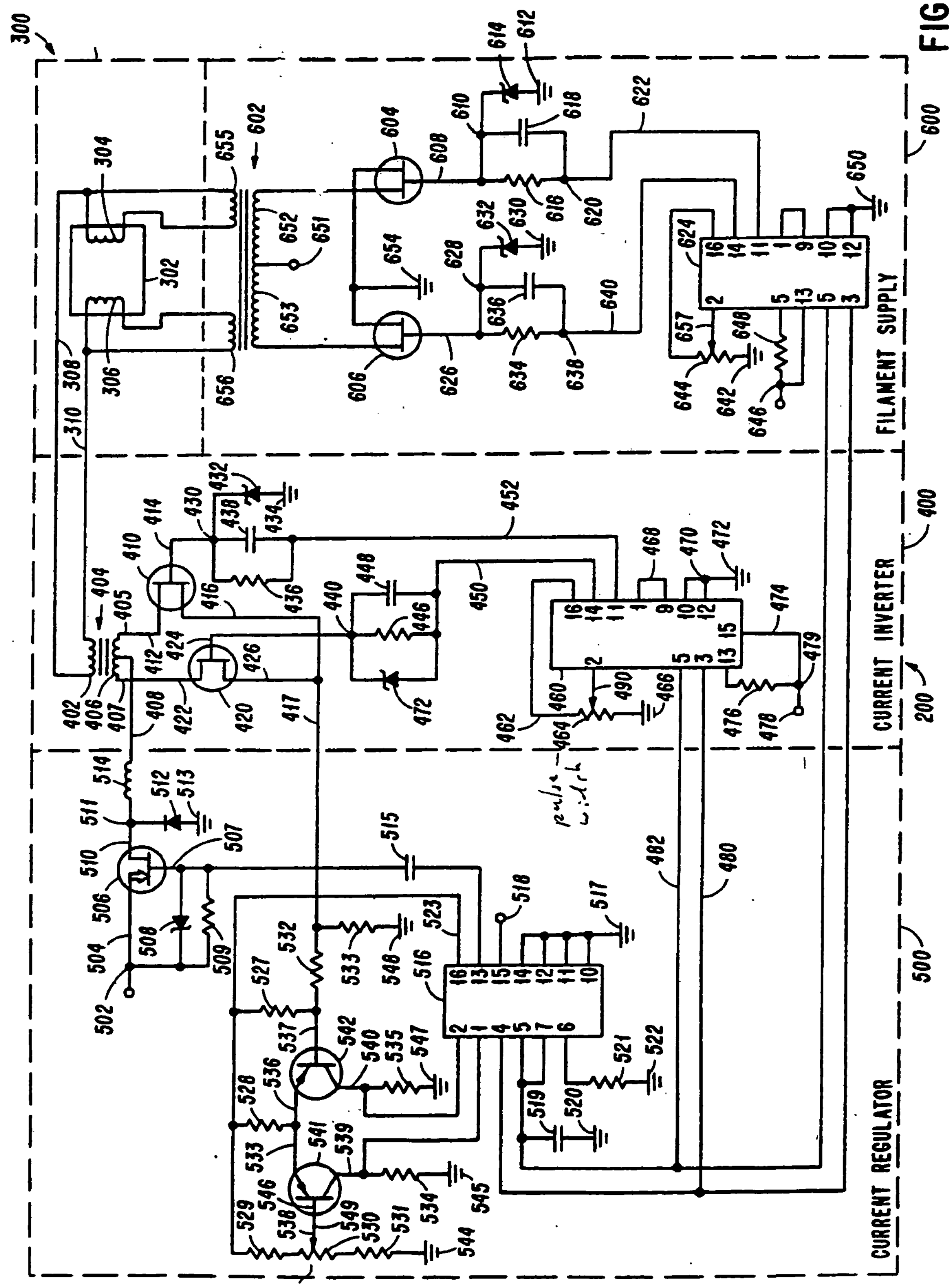


FIG 1

FIG 3




FILAMENT SUPPLY
CURRENT INVERTER
CURRENT REGULATOR
FIG 2

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FLUORESCENT LAMP DIMMER

This invention generally relates to flat panel displays and more particularly relates to displays using fluorescent lamps as a back light and even more particularly is concerned with dimmable fluorescent back lights for flat panel displays.

With the recent upsurge in the use of LCD displays in avionics equipment, it is becoming quite desirable to provide a back light which produces a relatively constant light color while concomitantly being capable of brightness control or dimming over an extended range.

Incandescent lamps typically exhibit relatively easy brightness control over a wide range, however the output light color is often not constant over the dimming range. Conversely, fluorescent lamps have been known to typically provide a relatively constant output light color with varying levels of brightness, but achieving a wide brightness range has been difficult to implement.

One method that has been used in the past is disclosed in U.S. Patent No. 4,277,728 to Carlile Stevens which is entitled "Power Supply for a High Intensity Discharge or Fluorescent Lamp", which patent is incorporated herein by this reference. The Stevens lamp utilizes a switching voltage regulator and a voltage inverter to control the voltage supplied to the lamp. Furthermore, this design utilizes a resonant network interposed between the voltage inverter and the lamp.

While this design has been used in the past it has numerous serious drawbacks. The lamp voltage manipulation approach of this design involves the use of a switching voltage regulator, voltage inverter, and a resonant network which can be difficult to implement and may be of large size and excessive weight. Further, the voltage manipulation approach does not make use of the observed direct functional relationship between fluorescent lamp brightness and the RMS current through the lamp, and thereby does not provide the advantages in size, weight, and cost of controlling this current directly. Moreover, the dimming ratio is often insufficient for certain avionics applications.

Consequently, a need exists for improvement in flat panel display back lights which result in the ability to provide a constant light color output over an extended brightness range in a relatively easily implemented design, which utilizes the direct functional relationship between the lamp brightness and

the lamp RMS current, without utilizing a voltage manipulation approach..

SUMMARY OF THE INVENTION

It is an object of the present invention to provide a back light for a flat panel display which provides a relatively easily implementable light which provides an extended brightness range and relatively constant color output.

It is a feature of the present invention to utilize a current regulator in combination with a fluorescent lamp.

It is an advantage of the present invention to directly vary the brightness of the tube by regulating lamp current.

It is another object of the present invention to provide a fluorescent lamp with an extended dimming range.

It is another feature of the present invention to provide a current inverter together with a current regulator.

It is another advantage of the present invention to provide for increased dimming at a given current level.

The present invention provides an extended dimming range constant color output flat panel display which is designed to satisfy the aforementioned needs, fulfill the earlier propounded objects, contain the above described features, and produce the previously stated advantages. The invention is carried in a "direct manipulation" and a "nonresonant" design in the sense that no resonant networks are present. Instead, the current is controlled directly without a resonator network.

Accordingly, the present invention relates to an apparatus for regulating the brightness of a fluorescent lamp over a wide range which includes a current regulator and a current inverter.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention may be more fully understood by reading the following description of the preferred embodiments of the invention in conjunction with the appended drawings wherein:

Fig. 1 is a block diagram representation of the flat panel display back light of the present invention showing in block form the current inverter disposed between the current regulator and the fluorescent lamp.

Fig. 2 is a more detailed electronic schematic representation of a preferred embodiment of the present invention.

Fig.3 is a schematic representation of a pulse width modulator chip which may be utilized as a part of the present invention.

DETAILED DESCRIPTION

Refer now to the drawings, and more particularly to Fig. 1. There is shown a flat panel display back light generally designated 100, including a current regulator 110 coupled with a current inverter 120 which is coupled with a fluorescent lamp 130. Current inverter 120 provides an AC current to the fluorescent lamp from the DC current which is output from the current regulator.

Now referring to Fig. 2 there is shown a more detailed electronic schematic representation of the lighting system of Fig. 1 which includes a back light generally designated 200, which includes a fluorescent lamp 300, a current inverter 400 and a current regulator 500 together with a filament supply 600.

Fluorescent lamp 300 includes a fluorescent tube 302 having a first filament electrode 304 and a second filament electrode 306 which are connected to the current inverter by first filament line 308 and second filament line 310, respectively. Fluorescent tube 302 is preferably operated by supplying an AC current through lines 308 and 310 which is provided by the current inverter 400.

Current inverter 400 includes apparatus to convert a DC current in line 408 to an AC current in the secondary windings 402 of current transformer 404. The current through primary winding 406 of transformer 404 is alternated by providing alternate current paths of the DC current provided on line 408. First transistor 410 and second transistor 420 are variably operated in order to provide variable current paths through the primary windings 406 of current transformer 404. Drain 412 of transistor 410 is connected with a first end 405 of primary windings 406 while drain 422 of transistor 420 is connected with a second end 407 of primary winding 406. Depending upon the selectable voltages on gates 414 and 424, current can be regulated through the sources 416 and 426 of transistors 410 and 420, respectively. Both sources are commonly connected with return line 417. First gate 414 is connected to pin 11 of pulse

width modulator 460 by line 452 through capacitor 438 and node 430; resistor 436 being arranged from node 430 across capacitor 438 to line 452 while zener diode 432 extends from node 430 to reference voltage 434.

Similarly, gate 424 of transistor 420 is connected to pin 14 of pulse width modulator 460 by line 450 through capacitor 448 to node 440. Resistor 446 and zener diode 442 are connected in parallel across capacitor 448 from node 440 to line 450. Pin 16 of pulse width modulator 460 is connected to reference voltage 466 by line 462 through potentiometer 464 which is connected by its slider terminal 490 to pin 2 of pulse width modulator 460. Pins 1 and 9 are interconnected by line 468, while pins 10 and 12 are connected to voltage reference 472 through node 470. Pins 5 and 3 are connected to lines 482 and 480, respectively, while pin 13 is connected to node 479 through resistor 476. Node 479 being connected with pin 15 by line 474. Input/output 478 being connected to node 479.

In operation, transistors 410 and 420 are variably manipulated in order to allow for differing current paths through primary winding 406 of current transformer 404. Pulse width modulator 460, through lines 452 and 450 and intermediate circuitry, regulate the current paths through transistors 410 and 420, respectively. Pulse width modulator 460 responds to adjustments in the setting of potentiometer 464 by varying the time periods (pulse widths) during which transistors 410 and 420 are alternately turned

on. This effectively constitutes a dimming control in addition to the dimming control provided by varying the current on line 408.

Current regulator 500 regulates the current on line 408. A reference supply voltage is placed on node 502 which is connected to source line 504 of transistor 506 which has its gate 507 separated from reference voltage 502 by zener diode 508 and resistor 509 in parallel. Drain 510 of transistor 506 is connected to node 511, while diode 512 connects reference voltage 513 with node 511, and inductor 514 connects node 511 with line 408. Gate 507 of transistor 506 is connected through capacitor 515 to output pin 13 of pulse width modulator chip 516. Pins 10, 11, 12, and 14 of chip 516 are connected to ground reference voltage node 517 while pin 15 of chip 516 is connected to reference voltage 518. Pins 5 and 7 of chip 516 are connected together and through capacitor 519 to ground reference node 520. Also, pins 5 and 7 are connected to pin 5 of pulse width modulator 460 and to pin 5 of pulse width modulator chip 624. Pin 6 of chip 516 is connected through resistor 521 to ground reference node 522 while pin 4 of chip 516 is connected to pin 3 of both chip 460 and chip 624. Reference pin 16 of chip 516 is connected through line 523 to bias resistors 527, 528, and 529. The remaining terminal of resistor 528 is connected to emitters 533 and 536 of transistors 541 and 542, respectively. The remaining terminal of resistor 527 is connected to base 537 of transistor 542 as well as to one terminal of resistor 532. The remaining terminal of resistor 529 is connected on one fixed terminal of control

potentiometer 530. The other fixed terminal of potentiometer 530 is connected to through resistor 531 to ground reference node 544. Slider terminal 538 of potentiometer 530 is connected to base terminal 546 of transistor 541. Collectors 539 and 540 of transistors 541 and 542, respectively, are connected to input terminals 1 and 2, respectively, of chip 516 and through resistors 534 and 535 respectively, to ground reference nodes 545 and 547, respectively. Current return line 417 is connected to the remaining terminal of resistor 532 and through resistor 533 to ground reference node 548.

The operation of pulse width modulator 516 is to switch transistor 506 to its on state, by way of output pin 13, capacitor 515, and gate 507. Current then builds up in inductor 514 and in current line 417 in accordance with the inductance voltage equation: e = Ldi/dt. The increasing return current in line 417 develops a feedback voltage across sensing resistor 533. This feedback voltage across sensing resistor 533 is shifted in level by resistors 527 and 532 and applied to the inverting input base 537 of transistor 541 which can be viewed as a differential error amplifier. The current command signal 549 from control potentiometer 530 is applied to the non inverting input base 546 of transistor 542, which also can be viewed as a differential error amplifier. The level shifted return current in line 417 is thereby compared with input current command signal 549, and the resulting amplified difference error signal is applied to input pins 1 and 2 of chip 516. When this input signal

becomes positive in polarity, chip 516 causes transistor 506 to be switched to its off state. This action is by way of the output pin 13, capacitor 515 and gate 507. Transistor 506 continues in its off state for the remainder of the clock period which is established by capacitor 519 and resistor 521. The action of pulse width modulator chip 516 is thereby to cause the current in inductor 514 to build up to a commanded level at the beginning of each clock period. This establishes the current input in line 408 of the current inverter 400.

The filament supply 600 supplies and regulates the current through first electrode filament 304 and second electrode filament 306. The filament supply of 600 provides a transformer 602 which is coupled with the first electrode filament 304 and the second electrode filament 306. The transformer 602 is coupled with a first filament transistor 604 and a second filament transistor 606. Gate 608 of transistor 604 is coupled to node 610 and to reference voltage 612 through zener diode 614. Resistor 616 and capacitor 618 are connected in parallel from node 610 to node 620 on line 622 which extends to pin 11 of pulse width modulator 624. Gate 626 of transistor 606 is connected to node 628 and to reference voltage 630 through zener diode 632. Resistor 634 and capacitor 636 are connected in parallel from node 628 to node 638 on line 640 which extends to pin 14 of pulse width modulator 624, which has its pin 16 extending to reference voltage 642 through potentiometer 644 which is coupled by its slider terminal 657 with pin 2. Pin 5 is

connected to supply voltage 646 through resistor 648 while pin 3 is directly connected to supply voltage 646. Pins 1 and 9 are directly inter-connected. Pins 10 and 12 are connected to reference voltage 650. The filament supply circuit 600 functions such as to cause windings 652 and 653 to be alternately switched between supply voltage 651 and ground reference node 654, thereby generating the alternating voltage that is applied to the filament 304 and 306 by way of windings 655 and 656 of transformer 602. This is accomplished by pulse width modulator chip 624 whose inputs 11 and 14 are connected through capacitors 618 and 636, respectively, to gate$608 and 626, respectively, of transistor 604 and 606, respectively. The alternating voltage thereby generated is of the form of alternating rectangular pulses, of width determined by the command signal 657 from potentiometer 644 and applied to pin 2 of chip 624. This signal may be varied with the brightness command as a way to conserve power and extend lamp life time.

Command signals 549 and 490 from both potentiometers 530 and 464 are found to exercise control over the brightness of the lamp 302. Control from potentiometer 530 is by way of the influence of current level, while control from potentiometer 464 is by way of influence of pulse width. It has been found that the two control influences are to some extent additive, thereby allowing more brightness control when exercised together than when either is exercised alone.

It should be recognized that control potentiometers 530,

464, and 644 are only illustrative of a manner of generating control signals 549, 490 and 657. These signals could be provided in other ways, wherein each signal is generated from a master dimming signal. The master dimming signal may be either analog or digital in nature, depending upon the requirement of the application.

Pulse width modulators 460, 516 and 624 are preferably S61525A or similar chips available from Intersil, but any chip which is substantially similar to the diagram in Figure 3 which are able to perform the desired functions may be substituted.

It is thought that the lighting system of the present invention any many of its intended advantages will be understood from the foregoing description, and it will be apparent that various changes may be made in the form, construction, and arrangement of the parts thereof without departing from the spirit and scope of the invention, or sacrificing all of their material advantages, the forms hereinbefore described being merely preferred or exemplary embodiments thereof. It is the intention of the appended claims to cover all such changes.

Reference should also be made to our copending patent application no. 8824056 entitled "Method and apparatus for controlling the brightness of a fluorescent lighting system" which claims priority from United States patent application no. 113043 by David N. Giebler.

CLAIMS

1. A brightness regulated fluorescent lighting system comprising:

a. a fluorescent lamp;

b. a current supply line connected with the fluorescent lamp for supplying the current to arc across the lamp;

c. a reversible current transformer, connected to the current supply line;

d. a DC current source;

e. a switchable DC current line connected with the DC current source;

f. an inductor connecting the current transformer and the DC current line;

g. means for regulating the switchable direct current line; and

h. means for controlling the reversible current transformer;

Whereby, the direct current in the switchable direct current line is selectively switched to allow current to the inductor in discreet bursts, which then is delivered to the reversible current transformer where the DC current is converted to the AC current in the current supply line and delivered to the fluorescent lamp so that the brightness of the lamp can be regulated by regulating the current to the inductor and by varying the pulse width of the AC current to the lamp.

2. A fluorescent lamp dimming control apparatus comprising:

a. means for supplying a directly regulated DC current;

b. means for inverting the DC current to AC current and supplying the AC current to a fluorescent lamp.

3. An apparatus of Claim 2 wherein said means for inverting the DC current comprises:

a. a current transformer having a first current path therethrough and a second current path therethrough;

b. a first transistor connected with the first current path for selectively switching the first current path;

c. a second transistor for switching the second current path;

d. means for controlling the first transistor and the second transistor in order to produce an AC current in the current transformer with a variable pulse width.

4. An apparatus of Claim 3 wherein the means for supplying a directly regulated DC current further comprises:

a. a current sensing resistor connected with the drain of the first transistor and the drain of the second transistor;

b. means for comparing the voltage across the current sensing transistor with a predetermined selectable voltage;

c. an inductor means;

d. means for regulating a DC current through a DC current field effect transistor connected to the inductor means.

5. An apparatus of Claim 4 further comprising the means for regulating the first transistor and the second transistor being operated in synchronism with the means for controlling the DC current transistor.

6. A method for controlling the brightness of a fluorescent tube comprising the steps of:

a. supplying a DC current through an inductor by means of switching a direct current field effect transistor in response to a input signal;

b. transforming the DC current to an AC current by passing it through alternate current paths in a current transformer;

c. 'regulating the AC current out of the current transformer by manipulating the pulse width of the current through the alternate current paths in the current transformer;

d. monitoring the current through the alternate current paths and comparing the current level with a selectable predetermined current level.

7. A method of Claim 6 further comprising the steps of operating the DC current field effect transistor in synchronism with the current transformer

8. An apparatus for controlling the brightness of a fluorescent tube comprising:

a. means for supplying a DC current through an inductor by means of switching a direct current field effect transistor in response to a input signal;

b. means for transforming the DC current to an AC current by passing it through alternate current paths in a current transformer;

c. means for regulating the AC current out of the current transformer by manipulating the pulse width of the current through the alternate current paths in the current transformer;

d. means for monitoring the current through the alternate current paths and comparing the current level with a selectable predetermined current level.

9. An apparatus of Claim 8 further comprising the means for operating the DC current field effect transistor in synchron6sm with the current transformer

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